

Soybean Yield Gap Analysis in Sukhothai : Agronomic Activities^{1/}

Abstract

An attempt to analyse the yield difference between the experimental yield of soybean monitored by researchers and actual farm yield done by farmers or the gap between the potential yield in the farm environment and the actual farm yield is made between 1989 and 1990 crops year in rainfed areas of Sawankhalok, Si Satchanalai, Si Nakhon and Si Samrong districts in Sukhothai province. The intent of the agronomic trials was to find solutions to existing problems of soybean production in the selected locations and generate appropriate recommendation for farmers. The trial was conducted by employing the IRRI approach. Three types of field experiments were done : complete factorial, minifactorial and maximum yield supplement. Three factors; namely weed control, fertilizer and insect control were tested individually or combining among two factors and three factors. The experimental design used in both 1989 and 1990 trials was RCBD. The results in both years revealed that the difference between treatments were insignificant for yield in all locations. For the demonstration fields, the considerable variations in yield between farmers using free inputs as well as farmers using existing technology was found. In 1989 trial, the yield obtained from the farmers with free inputs ranged from 0.75 to 2.50 t/ha while the yield from the field practiced with farmers' technology ranged from 0.80 to 2.07 t/ha. and the yield gap between the two groups were ranged from 7.03 % to 19.24 % The contribution of the fertilizer toward the yield appeared to be the greatest (127.08 kg/ha) followed by insect control and weed control (26.04 kg/ha and 16.44 kg/ha) respectively. However, the combine analysis showed no statistical difference among treatments. The adverse climatic condition especially the below average rainfall plus the damaging by pest seemed to be the responsible factors.

The result of the 1990 trial plot followed the same trend of the 1989 data. There was no significantly difference among yield obtained from any treatments. The abnormal rainfall pattern was, again the responsible factor. the comparison between the farmer input plot and the free input plots showed the greater yield of the latter one than the first. It replied the facts that Sukhothai farmers were reluctant to invest more input due to the two executive years of adverse climatic condition

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Introduction

Due to large demand of soybean for industrial uses, production of soybean has never met the domestic consumption. This indicates that materials used by several diverse industries involve soybean grain or its product. Beside this important role plays by soybean and government efforts in soybean research, the average soybean grain yield per area is still low as compared to other leading soybean producing countries. Preliminary survey (Sarobol et al., 1978) revealed the existence of yield gap between soybean yield of on-station research and soybean yield from farmer's field. Thus, the Soybean Yield Gap Analysis Project in Thailand was initiated with the financial assistance from the CGPRT center, Bogor, Indonesia with the over all objective of alleviating the constraints to soybean yield so as to increase soybean productivity in Thailand.

Materials and Methods

Tambons Wang Luek, Nong Klab, Tha Chai and Nam Khun of Si Samrong, Sawankhalok, Si Satchanalai and Si Nakhon Districts, respectively, in Sukhothai province were selected to implement the project during May-October 1989. Those areas represent the major soybean producing areas in the wet season of Sukhothai province as well as the others.

To investigate soybean production constraints in Sukhothai, in 1989 the omission trial or step-wise trial was designed to test on-farm. Three major factors (weed, fertilizer and insecticide) contributed to soybean yield reduction, as indicated by the preliminary survey, were tested as detailed in the appendix 1 and 2.

Two groups of five farmers from each tambon were selected to participate in the project. In 1989, one group of farmers received free, recommended production inputs (i.e., seeds, fertilizer, herbicide and insecticide). Another group received free recommendation but Provided themselves with the inputs they selected. The expection is that the 'potential yield' is obtained from the first group and the 'actual yield' is obtained from the second group. In addition one leading farmer was selected to join the project without receiving any free inputs except for the technical advice from the SYGAP team. The idea was to observe his activity and crop yield as compared to the participated farmers since he is an advanced farmers using intensive inputs and farming techniques.

The criteria for selecting the participating farmers were as follows:

1. willingness to participate in the project and/or to improve his soybean yield
2. ones whose cultural practices and inputs used are similar to his neighbors or the majority of villagers
3. ones who are ready to devote part of their fields to demonstrate production package of technology.

The recorded data include information on agrosocioeconomic aspects.

During May-October 1990, the project was implemented in the same areas with the same farmers except for some trial plots which encountered drought in 1989 were changed to more suitable plots. The omission trial and the superimpose trial were performed in the same districts as in 1989. Detailed of the trials one given in appendix 3.

Results and Discussion

The three factors (weed control, fertilizer and insect control) were tested in the trial plots. The results from the complete factorial trial (trial A) is shown in table 1 and table 2. The yield gap, computed from the difference between the yield obtained from the high-inputs plot and the farmers input plot were ranged from 7.03 % - 19.24 % (table 1). The high-inputs plot or the plots received the complete Package of production technology yield greater than the plots that farmers supplied their own inputs.

Table 1 Yield and yield components of soybean variety S.K.1 planted during the wet season of 1989 in Sukhothai province.

Location	Yield (kg/ha)		100-seed-wt.		Pods/pl.		Pl.ht.(cm.)		Yield gap	
	High Inputs	input	H.I	F.I	H.I	F.I	H.I	F.I	kg/ha	%
Si Samrong	750	802.76	8.2	9.2	19.7	29.7	73.3	84.4	(52.76)	(7.03)
Sawankhalok	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Si Satchanalai	2111.11	1883.34	14.2	14.4	28.5	31.6	70	63.1	222.77	10.79
Si Nakhon	2566.67	2072.22	14.1	15.5	38.1	24.7	94.4	95.9	494.45	19.24
mean	1809.26	1586.11	12.2	13	28.8	28.7	79.2	81.1	223.15	12.33

n.a =not available due to farmers mixed the yield obtained from experimental plots with his own plots

Note : The figures were computered from 2 replication per location or farm in trial A.

Table 2 Grain yield (kg/ha) of soybean obtained from the complete factorial trials (wet season 1989).

Treatment	Si Samrong	Sawankhalok	Si Satchanalai	Si Nakhon	Mean
1	802.76	Damaged	1,883.34	2,072.22	1,586.11
2	977.77		1,416.66	2,372.22	1,588.88
3	869.44		1,950.00	2,333.33	1,717.59
4	705.55		2,122.24	2,238.87	1,688.89
5	769.45		2,155.56	2,333.34	1,752.78
6	866.66		1,594.46	2,155.57	1,538.90
7	627.78		2,027.78	2,238.89	1,631.48
8	750.00		2,111.11	2,566.67	1,809.26
9	430.55		1,011.10	1,966.66	1,136.10
10	536.12		1,500.00	2,555.56	1,530.56
11	861.11		2,050.01	1,711.11	1,540.74

Note : 1. Average of two replications per location or farm.

2. No grain yield data from Sawankhalok because farmer mixed the seeds obtained from experimental plots with seeds from his own plots.

Table 3 Grain yield (kg/ha) contribution of test factors by districts or by farms (wet season 1989).

Districts	test factors			
	weed control	fertilizer	insect control	residual
Si Samrong	89.59	-84.01	-117.34	-
Si Satchanalai	-176.39	306.93	112.51	-
Si Nakhon	136.12	158.34	45.84	154.15
Mean	16.44	127.08	26.04	53.59

Note : 1. Absence of interactions of the test factor.

2. Computed from the complete factorial trials.

Table 4 Yield and yield components of soybean variety S.K.I planted in the wet season of 1989 at Si Satchanalai district (trial A).

Treatments	Yield (t/ha)	100-seed-wt. (g)	Pods/pl.	Pl. ht. (cm)
1	1.88	14.4	31.6	63.1
2	1.42	13.4	20.6	59.4
3	1.95	13.7	21.5	69.7
4	2.12	14.7	26.8	72.7
5	2.16	13.7	19.7	66.9
6	1.59	14.0	18.6	61.7
7	2.03	13.9	23.0	69.8
8	2.11	14.2	28.5	70.0
9	1.01	12.5	19.6	58.5
10	1.50	13.7	19.5	61.0
11	2.05	13.6	28.9	69.5
Mean	1.08	13.8	23.5	65.6
C.V. (%)	26.0	7.5	33.0	12.0
F-test	NS	NS	NS	NS

Table 5 Yield and yield components of soybean variety S.K.1 planted in the wet season of 1989 at Si Nakhon district (trial A).

Treatments	Yield (t/ha)	100-seed-wt. (g)	Pods/pl.	Pl. ht. (cm)
1	2.07	15.5	24.7	95.9
2	2.37	16.5	23.7	86.4
3	2.33	14.6	31.4	91.8
4	2.24	14.6	33.6	84.5
5	2.33	14.8	31.1	96.4
6	2.16	14.3	28.3	100.4
7	2.24	15.9	23.4	92.3
8	2.57	14.1	38.1	94.4
9	1.97	14.7	33.1	100.3
10	2.56	14.6	32.1	88.0
11	1.71	14.0	24.9	92.5
Mean	2.23	14.9	29.5	93.0
C.V. (%)	14.7	5.3	20.7	7.1
F-test	NS	NS	NS	NS

Table 6 Yield and yield components of soybean variety S.K.1 planted in the wet season of 1989 at Si Samrong district (trial A).

Treatments	Yield (t/ha)	100-seed-wt. (g)	Pods/pl.	Pl. ht. (cm)
1	0.80	9.2	29.7	84.4
2	0.98	10.1	30.5	83.8
3	0.87	8.9	29.2	86.3
4	0.17	9.0	30.3	73.3
5	0.77	9.5	25.5	79.6
6	0.87	10.0	34.7	79.6
7	0.65	9.3	28.5	74.4
8	0.75	8.2	19.7	73.3
9	0.43	9.2	33.3	68.8
10	0.54	8.7	14.7	74.4
11	0.86	9.6	36.5	89.4
Mean	0.75	9.2	28.8	78.8
C.V. (%)	44.4	9.4	25.1	13.0
F-test	NS	NS	NS	NS

Table 7 Grain yield (kg/ha) of soybean obtained from minifactorial trials (trial B)

Treatment code	Si Samrong	Sawankhalok	Si Satchanalai	Si Nakhon	Mean
5	1,265.00	1,185.00	2,695.00	2,758.31	1,975.83
6	1,086.25	1,000.00	2,370.00	2,920.81	1,844.26
7	1,145.00	1,430.00	2,880.00	2,795.81	2,062.70
8	1,030.00	1,135.00	2,870.00	2,129.19	1,791.05
1	830.00	780.00	2,847.50	2,554.19	1,752.92

Table 8 Individual and joint contributions of test factors to the increase of soybean yield (kg/ha) (wet season 1989)

Districts	Individual contribution			Joint contribution		
	Weed Control (W)	Fertilizer (F)	Insect Control (I)	W + F	W + I	F + I
Si Samrong	175.01	66.68	(97.21)	(33.31)	63.90	(174.98)
Si Satchanalai	(466.68)	66.66	238.90	272.22	(288.88)	144.44
Si Nakhon	300.00	261.11	166.65	261.12	83.35	166.67
Mean	2.77	131.48	102.78	166.67	(47.21)	45.37

- Note : 1. Presence of interactions of the test factors
2. Computed from the complete factorial trials (trial A)

Table 9 Joint contributions of test factors to soybean grain yield (kg/ha) in the wet season of 1989.

Districts	Joint contribution		
	W + F	W + I	F + I
Si Samrong	435.00	256.25	315.00
Sawankhalok	405.00	220.00	650.00
Si Satchanalai	(152.50)	(477.50)	32.50
Si Nakhon	204.12	366.62	241.62
Mean	222.91	91.34	309.78

- Note : 1. Presence of interactions of the test factors
2. Computed from the minifactorial trials (trial B).

Table 13 Seed yield of soybean demonstration plots in 4 districts of Sukhothai in 1990.

Treatments	Seed yield in t/ha			Si Samrong	Mean
	Si Satchanalai	Si Nakhon	Sawankhalok		
1. F + H + I	1.52	1.06	1.51	1.91	1.50
2. F + FP + FP	1.54	1.11	1.26	1.54	1.36
3. FP + H + FP	1.29	1.05	1.36	1.34	1.26
4. FP + FP + I	1.49	0.90	1.26	1.39	1.26
5. All FP	1.24	1.11	1.18	1.06	1.15
Mean	1.42	1.05	1.31	1.45	1.31

F = Fertilizer

H = Herbicide

I = Insecticide

FP = Farmer's Practice

The data in table 2 were computerized to determine the magnitude of contributions of the test factors to soybean yield gap. The contributions of test factors, averaged across locations, were 16.44, 127.08, 26.04 and 53.59 kg/ha for weed control, fertilizer, insect control and residual term, respectively. Detail contributions of test factors by districts were indicated in table 3 and the yield components were given in table 1, 4, 5 and 6. The combined analysis of three locations (Si Nakhon, Si Samrong and Si Sachanalai districts) revealed the yield difference between locations. Si Samrong's plot yielded the least (table 2) due to crop damaged from flooding at the first planting time and the replanted crop was hit by drought at R_3 - R_4 stages of growth and more serious in R_5 - R_6 . Moreover, there was widely infestation of pest at R_5 - R_6 . However, the combined data showed no statistical difference among treatments. The yield from different locations of trial B (minifactorial trial, was shown in table 7.

As the interactions of test factors existed, complete factorial trials and minifactorial trials were performed to elaborate the two-factor contributions. The yield gap of individual test factor and interactions were calculated and illustrated in tables 8-10. Obviously, when either high level of weed control or fertilizer was applied individually, the yield increment was less than when the two factors applied together. The results were as follows.

Actual farm yield	1,681.36 kg/ha
High input yield	1,806.00 kg/ha
Yield performance gap	124.64 kg/ha
Individual contribution :	
Weed control (W)	2.78 kg/ha
Fertilizer (F)	131.48 kg/ha
Insect control (I)	102.78 kg/ha
Joint contribution :	
Weed control and fertilizer	169.65 kg/ha
Weed control and insect control	31.96 kg/ha
Fertilizer and insect control	196.46 kg/ha

Finally, the results from this wet season experiments were unsatisfactory as drought and flood occurred during the early planting period and drought hit at pod filling stage. As a consequence, considerable low yields were obtained at Si Samrong. As such, repetition of experiments is strongly recommended.

Results of the experiment, in 1990, in all districts but plot no.1 of Si Nakhon revealed nonsignificant different in grain yield among treatment means (table 11). The results seemed discouraging because the expectation has never met. Erratic rainfall is the culprit to these results. Monthly amount of rainfall in Sawankhalok (July, August and September), Si Nakhon (August and September) and Si Samrong (July and September) are less than normal (Sukhothai data on July, August and September) (table 12). Nevertheless, normal rainfall is found in Si Satchanalai. When the demonstration plots are considered (table 13) plots receiving technology package for soybean production yielded as great as other treatments. The conclusion is that farmers at Sukhothai province are at risk due to adverse climate and the abuse of pesticides.

Recommendation for Future Work

Since the production of soybean in the wet season in Sukhothai is a risky business for farmers as one can see from the experience of SYGAP between two years as well as the experiences learned by the other study. Thus, the detailed study in the integrated manner should be performed. For instance, the collaborative project on "Climatic factors affecting soybean yield in specific area in Sukhothai" would be of beneficial efforts. The interdisciplinary team i.e. an agronomist, soil scientist, economist, extensionist, agricultural-engineer plus the plant climatologist would be an effective one.



Table 12 Monthly rainfall (mm) of Sukhothai province.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Sukhothai ^{1/}	6.2	6.6	19.3	49.8	162.0	139.1	138.0	180.5	251.6	141.2	25.0	4.9	1,126.1
Sawankhaloke ^{2/}	1.2	3.9	3.8	34.7	134.6	134.2	115.6	133.9	205.5	117.1	31.7	2.0	918.2
	O	T	T	26.6	401.0	152.6	69.4	123.6	160.5	210.7	T	O	1,145.0
	(T)	(7.4)	(39.1)	(56.7)	(285.0)	(75.2)	(60.0)	(141.5)	(173.2)	(64.2)	(20.5)	(0)	(922.8)
Si Satchanalai ^{2/}	5.5	3.8	8.2	24.4	138.3	129.7	137.7	175.5	215.8	119.6	18.6	0.7	977.6
	O	O	O	38.9	334.6	55.5	67.9	183.3	135.9	218.0	16.7	0	1,050.8
	(0)	(0)	(4.8)	(8.5)	(288.4)	(121.6)	(49.0)	(173.7)	(185.1)	(196.8)	(17.7)	(1.0)	(1,046.6)
Si Nakhon ^{2/}	1.4	1.1	1.6	22.8	173.0	138.3	162.1	118.7	158.5	77.4	16.1	0	871.0
	17.5	O	n.a.	n.a.	482.3	180.0	n.a.	106.2	98.4	n.a.	n.a.	n.a.	-
	(0)	(0)	(11.1)	(38.3)	(417.9)	(51.9)	(63.7)	n.a.	n.a.	n.a.	n.a.	n.a.	-
Si Samrong ^{2/}	1.2	3.0	17.2	62.2	160.3	155.0	129.4	165.2	235.2	164.7	44.1	3.4	1,140.9
	3.8	0	35.5	9.4	308.4	240.8	61.8	229.4	166.2	174.3	T	O	1,229.6
	(2.3)	(2.0)	(13.8)	(120.5)	(253.2)	(144.1)	(96.5)	(167.0)	(147.4)	(94.9)	(45.2)	(0)	(1,086.9)

Source : Department of Meteorological, Climatology Division, 1991

Note : 1/ = Average monthly rainfall of 16 agromets in Sukhothai province during 1952 - 1989

2/ = Average monthly rainfall during 1971 - 1990

undeline = Monthly rainfall in 1989

() = Monthly rainfall in 1990

T = Trace amount of rainfall

Appendix 1

SYGAP Project Locations and Experimental Designs in Sukhothai

1. Designs of the experiments

Amphoe	Type and A	of number B	on-farm of C	trial samples D	Total
Si Samrong	1	1	3	5	$1A + 1B + 3C + 5D = 10$
Sawankhalok	1	1	3	5	$1A + 1B + 3C + 5D = 10$
Si Suchanalai	1	1	3	5	$1A + 1B + 3C + 5D = 10$
Si Nakhon	1	1	3	5	$1A + 1B + 3C + 5D = 10$

Note : 1. Selected sites should have yields lower than District yield average

2. Trial A represents complete factorial design

Trial B represents mini factorial design

Trial C represents maximum yield design

Trial D represents general farm samples

Trial A : Factorial design

Treatment No.	Weed control	Fertilizer	Insect control	Other factors constant or farmer's practices
1	1	1	1	1
2	5	1	1	1
3	1	5	1	1
4	1	1	5	1
5	5	5	1	1
6	5	1	5	1
7	1	5	5	1
8	5	5	5	1
9	2a	2f	5	1
10	3a	3f	5	1
11	4a	4f	5	1

Note : 1. Plot size 6×4 m

2. Each plot has 2 replications

3. Inputs

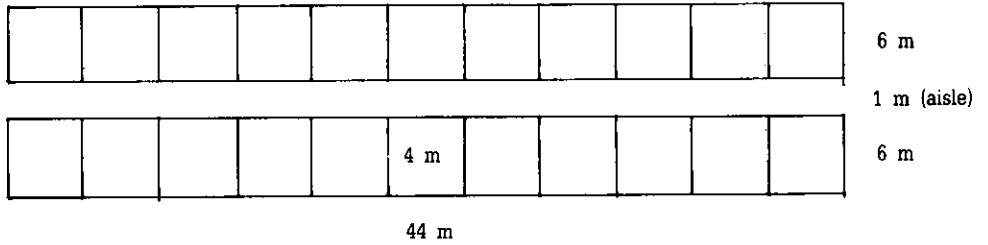
Level 1 = Existing farmers' practices

Level 5 = Practices with maximum yield

for example: 1. Rhizobium inoculation and 156.25 kg/ha of 12-24-12

2. Herbicide application, when needed

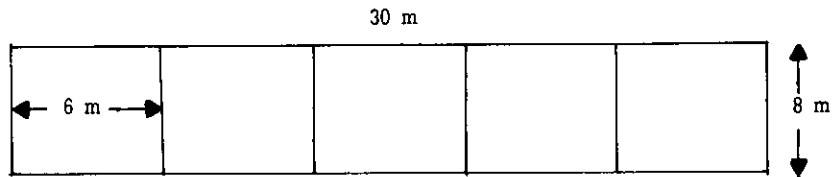
3. Precise pesticide, means of control threshold for pest management



- 4. Level 2a - Pre emergence
- Level 3a - Pre + pest emergence
- Level 4a - pre emergence + 1 hand weeding
- Level 2f - No fertilizer
- Level 3f - Rhizobium inoculation
- Level 4f - 12-24-12 at the rate 15 kg/rai
- 5. all plots expenses will be born by the project including Baht 500 for data information

Trial B : Mini factorial design

Treatment code	Treatment no.	Weed control	Fertilizer	Insect control	Other factors farmer's practices
T ₅	1	5	5	1	1
T ₆	2	5	1	5	1
T ₇	3	1	5	5	1
T ₈	4	5	5	5	1
T ₁	5	1	1	1	1 (check)



- Note :
- 1. Plot size 6×8 m
 - 2. 1 replication per polt
 - 3. Plot expenses are provided by the project
 - 4. Baht 500 for reward referred as data into

Trial C : Maximum yield design

- 1. Plot size 1 rai (1,600 aq.m.)
- 2. As note in Trial A Under Note # 3

Trial D: 1. 20 farm samples

- 2. Baht 4,000 for some free inputs (as necessary)

Appendix 2

Estimation of Yield Gap and Contribution of Test Factors for Sukhothai Site

1. Yield constraints experiments consist of three trials

1.1 Complete factorial trial (11 treatments, $T_1 - T_{11}$)

1.2 Minifactorial trial (15 treatments, $T_1, T_5 - T_8$)

1.3 Supplemental high inputs trial

2. Three test factors

2.1 Weed control

2.2 Fertilizer

2.3 Insect control

3. Two test factors level

3.1 Farmer's level

3.2 High input level

4. The estimation of yield gap and contribution of the test factors

4.1 With the absence of interaction among test factors

1) Yield performance gap

$$\text{Yield gap} = T_8 - T_1$$

2) Contribution of test factors

- Contribution of weed control

$$= (T_2 + T_5 + T_6 + T_8)/4 - (T_1 + T_3 + T_4 + T_7)/4$$

- Contribution of Fertilizer

$$= (T_3 + T_5 + T_7 + T_8)/4 - (T_1 + T_2 + T_4 + T_6)/4$$

- Contribution of insect control

$$= (T_4 + T_6 + T_7 + T_8)/4 - (T_1 + T_2 + T_3 + T_4)/4$$

3) Both 1 and 2 are computed from complete factorial trial

4.2 With the presence of interaction among test factors

1) Yield performance gap

$$\text{Yield gap} = T_8 - T_1$$

2) Individual contribution of test factors

- Contribution of weed control = $T_2 - T_1$

- Contribution of fertilizer = $T_3 - T_1$

- Contribution of insect control = $T_4 - T_1$

3) Joint contribution of test factor

- Contribution of weed control and fertilizer = $T_5 - T_1$

- Contribution of weed control and insect control = $T_6 - T_1$

- Contribution of fertilizer and insect control = $T_7 - T_1$

4) All the estimates are computed from complete factorial and minifactorial trials

Appendix 3

The omission trial and superimpose trial were performed during 1990. The omission trial was conducted at Si Samrong, Si Nakhon, Sawankhalok and Si Satchanalai districts and replicated 2 times in each district. The treatments were as follows :

Treatment	Weed control	Fertilizer	Insecticide	Other inputs
1	1	1	1	1
2	5	1	1	1
3	1	5	1	1
4	1	1	5	1
5	5	5	1	1
6	5	1	5	1
7	1	5	5	1
8	5	5	5	1

Where 1 = farmers' practice

5 = recommendation package

Sukthotai 1 was used in this trial. In each province, a field of 2 rai was planted to soybean with one treatment occupied the land of 180 m²

For the superimpose trial, the treatments were as follows :

Treatments	Weed control	Fertilizer	Insecticide
1	1	1	1
2	5	1	1
3	1	5	1
4	1	1	5
5	5	5	5

Where 1 = farmers' practice

5 = recommendation package

This trial was also conducted at Si Samrong, Si Nakhon, Sawankhalok and Si Satchanalai districts. Ten fields, of 1 rai each, were imposed in each district.

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